HADRONIC JOURNAL 49, 65 - 76 (2026)
DOI 10.29083/HJ.49.01.2026/SC65

PREDICTED STABILITY OF Z=119 SYSTEMS

J. J. Bevelacqua
Bevelacqua Resources
7531 Flint Crossing Circle SE
Owens Cross Roads, AL 35763
bevelresou@aol.com

Received January 18, 2026

Abstract

Single-particle energies of Z=119 nuclei are calculated to determine their decay properties. The Rost interaction is used as the basis for these calculations. A = 290 – 304 systems have predicted stability in the ps – ms range. The most stable isotope occurs at A = 297, and it has an alpha decay half-life of 0.112 s. These model results are consistent with the observed properties of Z = 110 – 118 nuclei.

KEYWORDS: Z=119, superheavy nuclei, alpha and beta decay half-lives, single-particle energies.

Copyright © 2026 by Hadronic Press, Inc., Palm Harbor, FL 34684, USA

1.0 Introduction

Superheavy nuclei and their associated stability have been active experimental and theoretical areas of research [1-28]. Calculations in the superheavy mass region require the selection of an appropriate nuclear interaction. The focus on Z = 119 and neighboring systems has been an area of active investigation as illustrated in [14, 22-28].

Calculations for the Z = 119 system are presented in this paper. These calculations determine the nuclear structure and predict the decay characteristics of the Z = 119 systems.

Z = 119 system stability is evaluated using the methodology Lukasiak and Sobiczewski [3] and Petrovich et al. [4]. The calculations are based on the unmodified Rost interaction [2]. Single-particle model calculations facilitate the investigation of superheavy systems that have yet to be experimentally detected and have received limited theoretical study [22-28]. These studies provide insight into binding energy systematics and nuclear stability beyond the previously established mass regions.

Using a more sophisticated method than the single-particle approach is not warranted in view of the uncertainties encountered in these initial calculations. These uncertainties include extrapolations of the nuclear interaction into the Z > 118 mass region. Since there are no experimental data to guide the calculations, single-particle calculations are a reasonable approach for initial calculations of Z = 119 nuclei [3,5,21].

The stability of Z = 119 systems is determined by evaluating the various decay modes (i.e., alpha decay, beta decay, positron decay, electron capture, and spontaneous fission). Based on previous calculations [1, 3, 5, 21-28], stability in the Z = 119 mass region is expected to be dominated by alpha decay.

2.0 Calculational Methodology

The model used to describe the particle (i) plus core (c) system represents an application of the standard method of Lukasiak and Sobiczewski [3] and Petrovich et al. [4]. The calculational method used to generate the single-particle level spectrum determines the binding energy E_{NLSJ} of a particle in the field of a nuclear core by solving the radial Schrödinger Equation

$$\left[\frac{\hbar^2}{2\mu}\left(\frac{d^2}{dr^2} - \frac{L(L+1)}{r^2}\right) - E_{NLSJ} - V_{LSJ}(r)\right] U_{NLSJ}(r) = 0 \qquad (1)$$

where r is the radial coordinate defining the relative motion of the nuclear core and the particle; $V_{LSJ}(r)$ is the model interaction; E_{NLSJ} is the core plus particle binding energy; $U_{NLSJ}(r)$ is the radial wave function; and L, S, and J are the orbital, spin, and total angular momentum quantum numbers, respectively. N is the radial quantum number and μ is the reduced mass. For the present application, V_{LSJ} is defined as:

$$V_{LSJ}(r) = -\frac{V_0}{1+exp\left(\frac{r-R_o}{a_o}\right)} - V_{so}\left(\frac{\hbar}{m_\pi c}\right)^2 \frac{1}{a_{so}r}\frac{exp\left(\frac{r-R_{so}}{a_{so}}\right)}{\left[1+exp\left(\frac{r-R_{so}}{a_{so}}\right)\right]^2}F(L,S,J) + Z_i Z_C e^2 C(r) \quad (2)$$

where

$$R_0 = r_0 A^{\frac{1}{3}} = R_C \quad (3)$$

and

$$R_{so} = r_{so} A^{1/3} \quad (4)$$

The parameters V_0, r_0, and a_0 are the strength, radius parameter, and diffuseness for the central potential. Similarly, V_{so}, r_{so}, and a_{so} are the corresponding parameters for the spin-orbit potential. To complete the specification of (2), we define:

$$F(L,S,J) = J(J+1) - L(L+1) - S(S+1) \quad (5)$$

and

$$C(r) = \frac{1}{2R_C}\left(3 - \left(\frac{r}{R_C}\right)^2\right) \quad for \quad r < R_C \quad (6)$$

$$C(r) = \frac{1}{r} \quad for \quad r \geq R_C \quad (7)$$

For the Coulomb potential, it is assumed that the particle is a point charge of magnitude $z_i e$. The core has a charge $Z_C e$ uniformly distributed through a sphere of radius R_C. Since the potential is not a function of the spherical coordinates, the

solution of the angular equation is most easily expressed in terms of spherical harmonics $Y_{LM}(\theta,\varphi)$.

The total bound-state wave function $\left(\Psi_{NLSJM}(\vec{r})\right)$ for the relative motion of the core plus particle, interacting through a spherically symmetric potential, is given by the product of space and spin wave functions:

$$\Psi_{NLSJM}(\vec{r}) = \frac{1}{r} U_{NLSJ}(r) \sum_{M_L M_S} C(L, M_L, S, M_S; JM) Y_{LM_L}(\theta,\varphi) \chi_{SM_S} \tag{8}$$

where M_L and M_S are the projections of angular momentum and spin, and χ is the spin wave function. For the calculation of single-particle energy levels, N, L, S, and J specify the quantum numbers of the single-particle level.

The binding energy of a single-particle level is obtained by rewriting the radial Schrödinger equation in the form

$$\left(\frac{d^2}{dr^2} - k(p,r)\right) U(p,r) = 0 \tag{9}$$

where

$$U(p,r) = U_{NLSJ} \tag{10}$$

and

$$k(p,r) = \frac{L(L+1)}{r^2} + \frac{2\mu}{\hbar^2}\left(E_{NLSJ} + V_{LSJ}(r)\right) \tag{11}$$

The model searches for values of the parameter p in order to obtain the binding energy E_{NLSJ} for a given potential. The method of searching for p is provided by Brown, Gunn, and Gould [29] using the methodology of [30] to obtain a converged solution. [2 - 4, and 21] provide additional details of the model, numerical methods, and associated interactions.

2.1 Determination of Q Values and Half-Lives

Alpha decay Q values are calculated using the relationship

$$\mathbf{Q_\alpha = 28.3\ MeV - 2\ S_n - 2\ S_P} \tag{12}$$

where S_n and S_p are the binding energies of the last occupied neutron and proton single-particle energy levels, respectively [1]. The alpha decay, positron decay, and electron capture half-lives were determined following the methodology noted in [3]. Spontaneous fission half-lived were qualitatively evaluated using the methodology of [3] and were not limiting [4,21].

The log ft methodology of Wong [1] is used to determine the beta decay half-lives. Allowed (first-forbidden) beta decay half-lives are obtained from the values of log ft = 5 (8) [1]. In view of the uncertainties in the calculated level energies, second and higher forbidden transitions were not determined. The beta half-lives summarized in Table 1 listed as *stable* are either beta stable or decay by these higher order forbidden transitions.

3.0 Nuclear Interaction

The model considers the single-particle spectrum generated by a Woods-Saxon potential with parameters optimized for extrapolation into the region of superheavy nuclei [4]. The parameters of the Rost potential were obtained from a fit to the particle levels in ^{208}Pb and ^{209}Bi [2].

The single-particle level spectrum is generated using a Woods-Saxon potential of the Rost interaction [2]. The Rost central interaction strength is given by the relationship:

$$V_0 = 51.6 \left[1 \pm 0.73 \frac{N-A}{Z}\right] MeV \qquad (13)$$

The potential for protons (neutrons) is given by the upper (lower) sign. The remaining parameters were held constant and are given by Rost [2]: r_0 = 1.262 (1.295) fm, r_{so} = 0.908 (1.194) fm, a = 0.70 (0.70) fm, and λ = 17.5 (28.2) for protons (neutrons). V_{so} is related to λ by the relationship [2]:

$$V_{so} = \frac{\lambda V_0}{180} \qquad (14)$$

The scaling relationship of (13) yields reasonable fits to observed single-particles levels in ^{120}Sn and ^{138}Ba [4]. The pairing correction term of Blomqvist and Wahlborn [31] is used in the calculations presented herein. The pairing correction improves the predicted energies of occupied levels in ^{120}Sn, ^{138}Ba, and ^{208}Pb [4]. A Woods-Saxon potential which reproduces the single-particle levels in the lead region provides the basis for a discussion of the stability properties of Z=119 superheavy nuclei [2,4].

4.0 Results and Discussion

Table 1 summarizes the results of Z = 119 single-particle level calculations. This table provides the alpha decay Q value and the alpha and beta decay half-lives for A = 290 – 304, Z = 119 systems. This mass range is consistent with the calculations summarized in [27] that reviewed the possible reactions that would theoretically produce the various Z = 119 isotopes.

The results suggest that A = 290 – 304 systems have predicted half-lives in the ps – ms range. Alpha emission is predicted to be the limiting decay mode. Table 1 also provide the valance neutron and proton single-particle (sp) levels for each of the calculated Z = 119 systems. The most stable Z = 119 isotope is predicted to occur at A = 297 with an alpha decay half-life of 0.112 s. Following [3], shell corrections are included in the alpha decay half-life and Q-value calculations.

Table 1

Z=119 Q_α and Half Life Values

A (p, n single-particle level)	Q_α (MeV)	$T_{1/2}^{\alpha}$	$T_{1/2}^{\beta}$
290 ($2f_{5/2}$, $2g_{7/2}$)	12.3	0.652 μs	15.7 min[a]
291($2f_{5/2}$, $2g_{7/2}$)	12.0	3.38 μs	17.3 min[b]
292 ($2f_{5/2}$, $3d_{5/2}$)	11.7	12.1 μs	18.9 min[b]
293 ($2f_{5/2}$, $3d_{5/2}$)	11.4	65.7 μs	20.7 min[b]
294 ($2f_{5/2}$, $3d_{5/2}$)	11.1	0.380 ms	22.8 min[b]
295 ($2f_{5/2}$, $3d_{5/2}$)	10.8	2.35 ms	25.1 min[b]
296 ($2f_{5/2}$, $3d_{5/2}$)	10.5	15.6 ms	27.8 min[b]
297 ($2f_{5/2}$, $3d_{5/2}$)	10.2	0.112 s	1.06 h[c]
298 ($2f_{5/2}$, $4s_{1/2}$)	12.1	1.85 μs	1.22 h[c]
299 ($2f_{5/2}$, $4s_{1/2}$)	11.8	9.23 μs	1.41 h[c]
300 ($2f_{5/2}$, $3d_{3/2}$)	11.6	31.1 μs	1.64 h[c]
301 ($2f_{5/2}$, $3d_{3/2}$)	11.3	0.175 ms	1.92 h[c]
302 ($2f_{5/2}$, $3d_{3/2}$)	10.9	1.05 ms	2.27 h[c]
303 ($2f_{5/2}$, $3d_{3/2}$)	10.6	6.79 ms	[d]
304 ($2f_{5/2}$, $2h_{11/2}$)	15.2	2.48 ps	[d]

[a] **First forbidden $2f_{5/2}$(p) to $2g_{7/2}$ (n) positron transition.**
[b] **First forbidden $2f_{5/2}$(p) to $3d_{5/2}$ (n) positron transition.**
[c] **First forbidden $2f_{5/2}$(p) to $3d_{3/2}$ (n) positron transition.**
[d] **Beta stable.**

The A = 297 single-particle level diagram for Z = 119 is provided in Fig. 1. The last occupied neutron (proton) single-particle level is $3d_{3/2}$ ($2f_{5/2}$). Half-life values for the Z = 119 systems are in the ps – ms range. Nuclear stability rapidly decreases beyond A = 303 as the valence neutron transitions from the $3d_{3/2}$ to $2h_{11/2}$ single-particle level. The decrease in the $2h_{11/2}$ neutron single-particle binding energy increases the Q_α value that leads to a shorter alpha decay half-life.

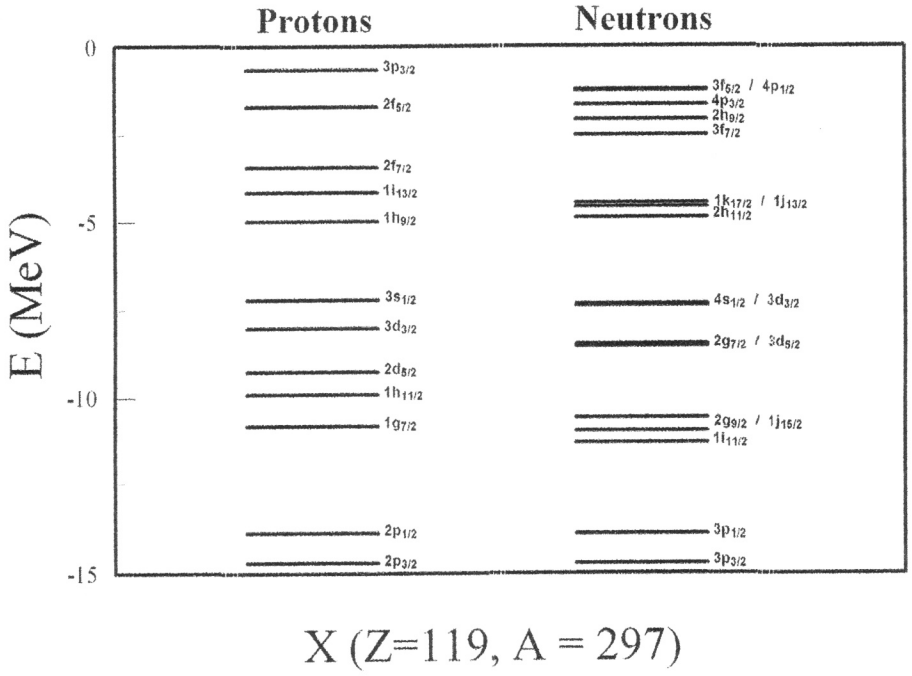

Fig. 1. Calculated single-particle levels for the most stable Z = 119 nucleus (A = 297). The notation a/b is used to indicate adjacent energy levels with level a more tightly bound than level b.

Qian and Ren [22] provide a set of Z = 119 calculations for A = 290 – 299. [22] predicts the decay mode will be alpha, but only provides a broad range of half-life values. For example, the [22] half-life values are in the range of 1.4×10^{-5} to 2.47×10^{3} s.

Table 2 compares the model results to Z = 110 – 118 systems to the experimental range of isotope masses, half-life range, and most stable system [32]. The Z = 119 model results appear to be consistent with the trends in Z = 110 - 118 mass and half-life values. Alpha decay is the dominant decay mode in most of these systems [32], and that is also consistent with the model results.

Table 2

Comparison of Z = 110 – 118 Data[a] and Z = 119 Model Results[b]

Z	Mass Range	Half-Life Range	Most Stable
110	267 – 282	3.0 μs – 1.1 min	^{282}Ds
111	272 – 282	3.8 ms – 100 s	^{282}Rg
112	277 – 286	0.61 ms – 11.0 min	^{286}Cn
113	282 - 290	70 ms – 9.5 s	^{286}Nh
114	284 – 290	25 ms – 19 s	^{290}Fl
115	287 – 290	37 ms -0.65 s	^{290}Mc
116	290 – 293	8.3 ms – 95 ms	^{293}Lv
117	293 – 294	21 ms – 51 ms	^{294}Tn
118	294	0.58 ms	^{294}Og
119	290 - 304	2.48 ps – 0.112 s	^{297}X

[a]Derived from NuDat3 [32].
[b]This work.

Within the scope of the model, the effective half-life of the Z = 119 systems includes the combined effect of the alpha and positron decay modes, and is defined as

$$T_{1/2}^{eff} = (T^{\alpha}_{1/2}\, T^{\beta}_{1/2}) / (T^{\alpha}_{1/2} + T^{\beta}_{1/2}) \qquad (15)$$

Since the positron decay half-life is much larger than the alpha decay half-life, the effective half-life is essentially the alpha decay half-life.

Based on previous calculations [3,4,21], spontaneous fission stability is expected to be enhanced near closed shells. These spontaneous fission calculations utilized the Wentzel-Kramers-Brillouin (WKB) approximation methodology and the phenomenological parameter values of [3]. The calculations suggest that fission half-lives near closed shells are greater than the effective decay half-lives calculated using (15).

5.0 Model Weaknesses

Model limitations include uncertainties in the nuclear interaction [2], exclusion of nonconventional decay modes that could exist in superheavy systems, and treating all system as spherically symmetric nuclei. In spite of these

uncertainties, the Rost interaction yields results that are consistent with the trends observed in Z = 110 – 118 systems.

The accuracy of the proposed model can be partially addressed by comparing the (Z, A) values of calculated system properties to the predictions of Adler's relationship [33,34]. The Alder relationship provides the most stable nucleus Z value for a given A:

$$\mathbf{Z = (0.487\ A) / (1 + A^{2/3} /166)} \qquad (16)$$

This relationship can be compared to the model predictions for the most stable A = 297 system. The Adler relationship predicts that the most stable A = 297 value occurs at Z = 114. This is about 4% smaller than the Z =119, A = 297 result obtained from the spherical model outlined in this paper. This comparison between the model and predictions of the Adler relationship of (16) suggests at least the qualitative usefulness of the proposed model.

7.0 Conclusions

Single-particle energies of Z=119 nuclei are calculated to determine their decay properties. The Rost interaction is used as the basis for these calculations. A = 290 – 304 systems have predicted stability in the ps – ms range. The most stable isotope Z = 119 is predicted to occur at A = 297 with an alpha decay half-life of 0.112 s. These results are consistent with the observed properties of Z = 110 – 118 nuclei.

References

1) C. Y. Wong, Additional evidence of stability of the superheavy element $^{310}126$ according to the shell model, Phys. Lett. **21**, 688-690 (1966).
2) E. Rost, Proton Shell-Model Potentials for Lead and the Stability of Superheavy Nuclei, Phys. Lett. **26B**, 184-187 (1968).
3) A. Lukasiak and A. Sobiczewski, Estimations of half-lives of far-superheavy nuclei with Z approx. = 154 - 164, Acta Phys. Pol. **B6,** 147-165 (1975).
4) F. Petrovich et al., Comments on Primordial Superheavy Elements, Phys. Rev. Lett. **37**, 558-561 (1976).
5) G. N. Flerov and G. M. Ter-Akopian, Superheavy Nuclei, Rep. Prog. Phys. **46**, 817 -875 (1983).
6) R. Smolańczuk, Properties of the hypothetical spherical superheavy nuclei, Phys. Rev. C **56**, 812 - 824 (1997).

7) M. Bender et al., Potential energy surfaces of superheavy nuclei, Phys. Rev. C **58**, 2126 -2132 (1998).
8) S. Hofmann and G. Münzenberg, The discovery of the heaviest elements, Rev. Mod. Phys. **72**, 733 -767 (2000).
9) S. B. Duarte et al,, Half-life predictions for decay modes of superheavy nuclei, J. Phys. G: Nucl. Part. Phys. **30**, 1487-1494 (2004).
10) H. Koura et al., Nuclidic Mass Formula on a Spherical Basis with an Improved Even-Odd Term, Prog. Theor. Phys. **113**, 305-325 (2005).
11) P. Mohr, α-nucleus potentials, α-decay half-lives, and shell closures for superheavy Nuclei, Phys. Rev. C **73,** 031301(R) to -5(R) (2006).
12) Yu. Ts. Oganessian et al., Synthesis of the isotopes of elements 118 and 116 in the ^{249}Cf and ^{245}Cm + ^{48}Ca fusion reactions, Phys. Rev. C **74**, 044602-1 to -9 (2006).
13) P. R. Chowdhury, C. Samanta, and D. N. Basu, Search for long lived heaviest nuclei beyond the valley of stability, Phys. Rev. C **77,** 044603-1 to -10 (2008).
14) V. Zagrebaev and W. Greiner, Synthesis of superheavy nuclei: A search for new production reactions, Phys. Rev C **78**, 034610-1 to -11 (2008).
15) C. Samanta, Alpha decay chains from superheavy nuclei, Prog. Part. Nucl. Phys. **62**, 344-348 (2009).
16) P. Möller et al., Heavy-element fission barriers, Phys. Rev. C **79**, 064304-1 to -38 (2009).
17) A. Marinov et al., Evidence for the Possible Existence of a Long-Lived Superheavy Nucleus with Atomic Mass Number A = 292 and Atomic Number Z ≅ 122 in Natural Th, Int. J. Mod. Phys. E **19**, 131-140 (2010).
18) D. N. Poenaru, R. A. Gherghescu, and W. Greiner, Heavy-Particle Radioactivity of Superheavy Nuclei, Phys. Rev. Lett. **107**, 062503-1 to -4 (2011).
19) Yu. Ts. Oganessian et *al*, Production and Decay of the Heaviest Nuclei ^{293,294}117 and ^{294}118, Phys. Rev. Lett. **109**, 162501-1 to -5 (2012).
20) K. Morita et *al*, New Result in the Production and Decay of an Isotope, ^{278}113, of the 13th Element, J. Phys. Soc. Japan **81**, 103201-1 to -4 (2012).
21) J. J. Bevelacqua, 570 ≤ A ≤ 620 Superheavy Nuclei, Physics Essays **25**, 475-483 (2012).
22) Y. Qian and Z. Ren, Predictions on properties of α decay and spontaneous fission in superheavy odd-*Z* nuclei, Phys. Rev. C **90**, 064308-1 to -8 (2014).
23) G. G. Adamian et al., Predictions of identification and production of new superheavy nuclei with Z = 119 and 120, Phys. Rev. **C** 101, 034301-1 to -13 (2020).
24) J. Khuyagbaatar et al., Search for elements 119 and 120, Phys. Rev. C **102,** 064602-1 to -9 (2020).

25) M. Tanaka et al., Probing Optimal Reaction Energy for Synthesis of Element 119 from $^{51}V+^{248}Cm$ Reaction with Quasielastic Barrier Distribution Measurement, Journal of the Physical Society of Japan **91**, 084201-1 to -11 (2022).
26) O.R. Smits et al., Pushing the limits of the periodic table — A review on atomic relativistic electronic structure theory and calculations for the superheavy elements, Physics Reports **1035**, 1–57 (2023).
27) R. Zargini and S. A. Seyyedi, Significance of the compound nucleus surface energy coefficients in the synthesis of superheavy nuclei with Z = 112–120, Phys. Rev. C **108**, 034606-1 to -13 (2023).
28) T. Wan, S-L. Tang, Y-B.Qian, α-decay properties of superheavy nuclei with $117 \leq Z \leq 120$ from the systematics of decay chains and isotopic chains, Chinese Physics C **48,** 034103-1 to -8 (2024).
29) G. E. Brown, J. H. Gunn, and P. Gould, Effective mass in nuclei, Nucl. Phys. **46**, 598-606 (1963).
30) L. Fox and E. T. Godwin, Some new methods for the numerical integration of ordinary differential equations, Proc. Cambridge Philos. Soc. **45**, 373-388 (1949).
31) J. Blomqvist and S. Wahlborn, Shell model calculations in the lead region with a diffuse nuclear potential, Ark. Fys. **16**, 545-566 (1959).
32) NuDat3, National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY. https://www.nndc.bnl.gov/nudat3/.
33) K. Adler, Coulomb Interactions with Heavy Ions, CONF-720669, Proceedings of the Heavy Ion Summer School, June 12 – July 1, 1972, Oak Ridge National Laboratory, Oak Ridge, TN (1972).
34) J. J. Bevelacqua, *Contemporary Health Physics: Problems and Solutions*, 2nd ed. (Wiley-VCH, Weinheim, 2009).